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Control of Cable Insulation Quality by Changing of Electrical Capacitance Per Unit During High Voltage Testing

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Abstract. The paper describes the complex method of insulation quality control. It was found that electrical contact between bead chain electrodes and insulation surface can be provided by surface discharges along the entire length of the controlled zone. The pattern of electromagnetic field was developed by using Comsol Myltiphysics software.

1. Introduction

One of the parameters, which have high influence on the operational characteristics of the cable product, is a quality of the insulation (continuity, external and internal geometry, chemical compounds). During the manufacture of the cable products it is necessary to provide continuous control of this parameter for timely correction of technological regime and reduction of mass spoilage probability of the products.

Nowadays mainly two methods of control during cable products manufacturing is used: the electro capacitive method [1] and the spark method [2] of control.

1.1. Electro capacitive method of control

Under the control of electric capacity the cable is passing through the cylindrical electrode, low voltage is applied to cable to measure the electrical capacity of the controlled area. To provide electric contact between cable insulation surface and the electrode water in cooling bath is used. Value of the linear electric capacity is changed if defected section of cable insulation passes through the controlled area.

1.2. Spark method of control

The spark method of control is performed with electrode (chain-type, spring-type or brush-type) through which high voltage is applied to the insulation surface. When defected section of cable insulation passes through the controlled area electrical breakdown occurs and it is registered with the automatics [3].

Described method of control does not allow detecting all types of the defects separately. Thus, the reliability of control is low [4,5]. To increase the reliability of cable insulation control it was suggested to combine two existing methods to the one complex method. Suggested complex method consists in measuring of electric capacity per meter during a spark testing of controlled cable (figure 1).

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The aim of this work is to assess the ability of reliable electrical capacity measurement during a spark testing of controlled cable.

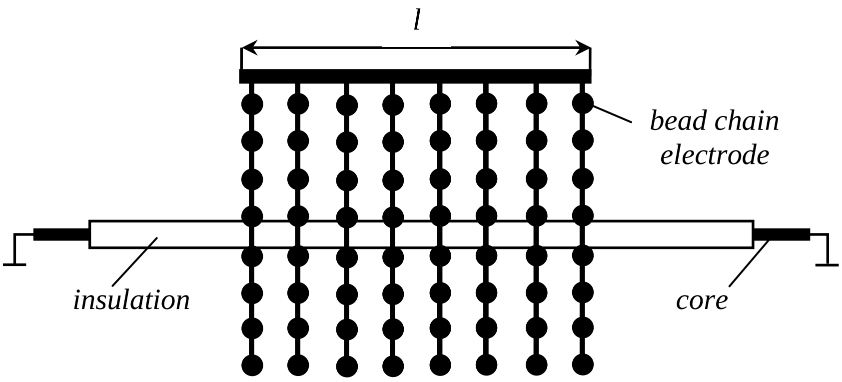

Figure 1. Theoretical model of the complex method of control.

2. Complex method of control

To provide reliable electrical capacity measurement it is necessary to apply test voltage to whole surface of controlled area, but not only to point of contact of electrode bead chain and insulation surface. It is realised in complex method due to high test voltage.

The electrode is presented as a set of chains (figure 1) therefore the electric field in control area is non-uniform. The figure 2 shows a diagram of electric field distribution in controlled zone at the initial moment of test voltage applying before appearance of ionisation processes. It may be concluded from the figure that normal component of electric field dominates over the tangential component. Predominance of the normal component leads to thermal ionisation, which eases the process of electrical discharge.

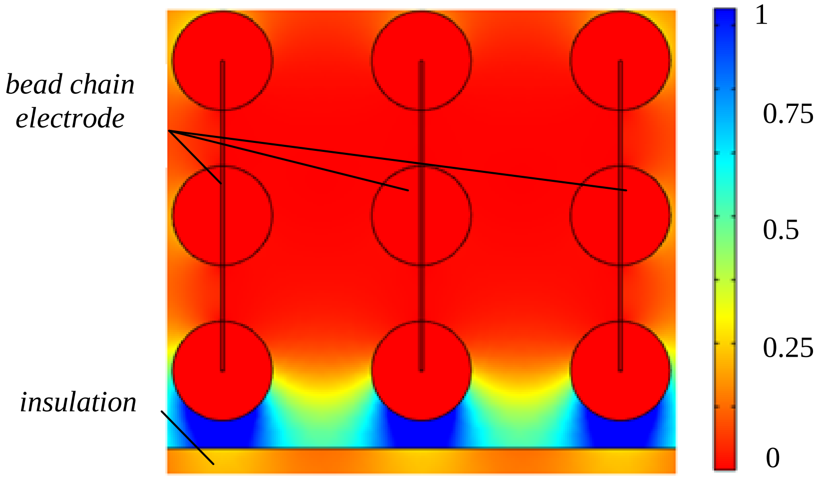

Figure 2. Electrical field distribution between bead chain electrode and cable insulation surface (maximal relative electric field intensity equals 1, minimal equals 0).

In presence electric field sliding discharge is occurred [6]. Different factors effect on the spreading of the sliding discharge. These factors are materials of cable insulation, state of insulation surface, type and value of the test voltage. Length of the sliding discharge can be calculated with empirical Tepler’s formula [7]:

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$$l_{\text{sd}} = k \cdot C^2 \cdot U^5 \cdot {\frac{dU}{dt}}^{1/4},$$

where k – empirical coefficient, C – specific surface capacity, U – voltage. Thereby, according to the Tepler formula, value of voltage and specific surface capacity have a significant influence on the length of sliding discharge spreading. To explore the test voltage distribution along an cable insulation surface the experiment was carried out.

3. Experimental part

For the experiment it was necessary to use device for applying and measuring of signal. Applying equipment was the system consisting of signal generator, power amplifier and high-voltage transformer. The measuring part consisted of oscilloscope divisor and digital oscilloscope. For applying and measuring were used ring-type electrodes. In current experiment test voltage was applied to the zero coordinate point and potential distribution along the surface of cable product was defined with measurement device.

After the experiments the dependences of the test voltage distribution along an insulation surface from test voltage parameters was obtained (figure 3).

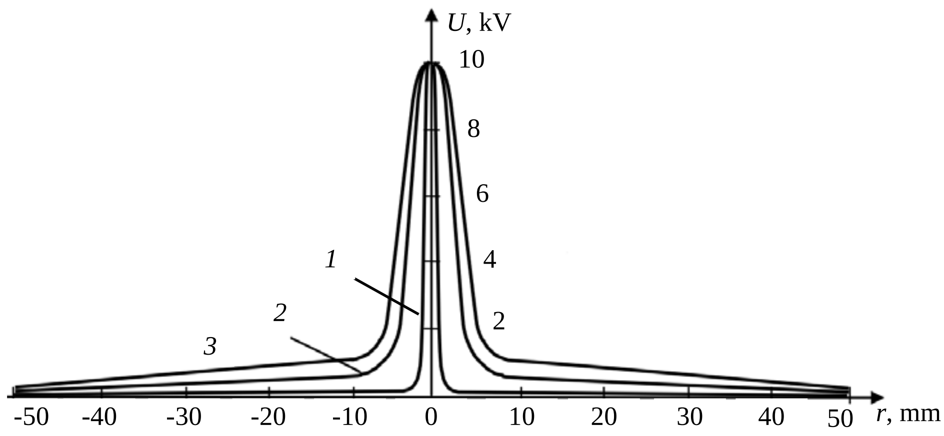

Figure 3. Distribution of the test voltage along the insulation surface with constant voltage (1), with alternating voltage with frequency 50 Hz (2), 1 kHz (3).

Dependences shown on the picture was obtained with the 10 kV test voltage value.

The obtained dependences for test voltages with values 3, 10 and 15 kV were analysed. As a result it is possible to conclude that noticeable distribution of the potential presents only with alternative voltage. It appears due to specific surface capacity of the insulation material, which is confirmed by Teplers formula. In case of direct voltage a specific surface capacity does not affect the spreading of the discharge. The discharge is similar to discharge in the air gap for this case.

Based on obtained dependences of voltage distribution, dependence of the electrode elongation from the type and value of voltage was theoretically found (figure 4).

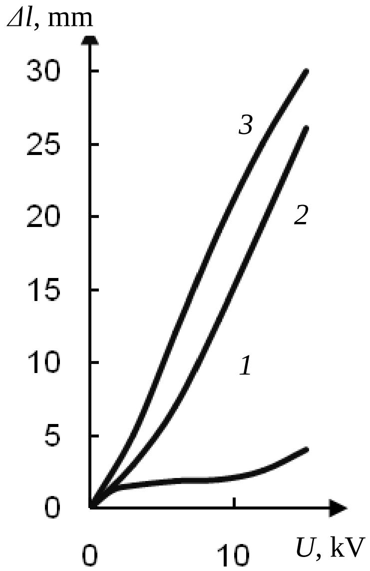

Figure 4. Dependence of electrode elongation from the value of the direct (1), and alternative voltage with 50Hz (2) and 1kHz (3) frequency).

4. Conclusion

Admitting the association of voltage distribution and the length of the sliding discharge it can be noted that value of applied alternating voltage has a significant influence on the electrode elongation, which is corresponds to the Tepler's formula. In case of direct voltage only small elongation of the electrode was found.

Analysis of the research results shows that appearance of the sliding discharge allows providing of electric contact between electrode and insulation surface not only at points of mechanical contact of electrode chains and cable insulation, but along the whole length of controlled zone using the alternating voltage.

5. Acknowledgments

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